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(54) **Constant power ballast**

(57) The present invention relates to a power supply for gas discharge light sources or any other form of gas discharge load. This invention consists of a switching regulator section (8) uniquely conditioned to present a unity power factor to the line input (1a and 1b), a switching inverter (16) that develops a high frequency which is presented through a network (19) to the gas discharge (22). The network (19) utilizing a means of unique feedback maintains a nearly sineusoidal voltage and current wave form through the gas discharge (22). The subject invention works to control the current through the discharge as a function of the voltage across it to maintain a constant wattage dissipation.

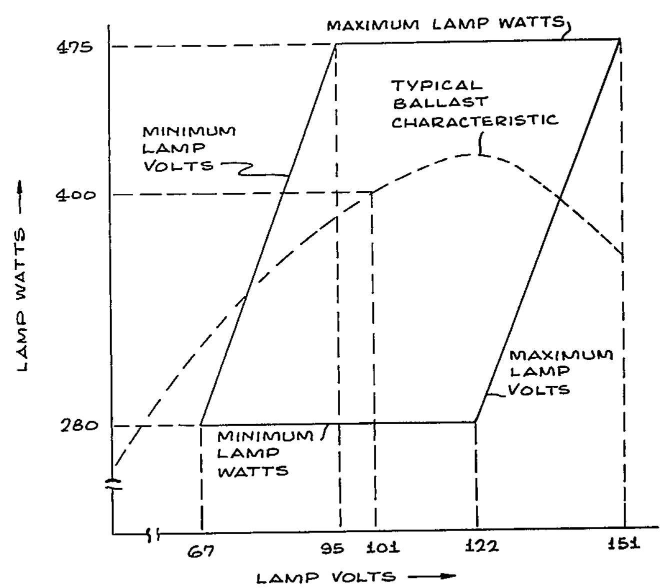

FIG. 1

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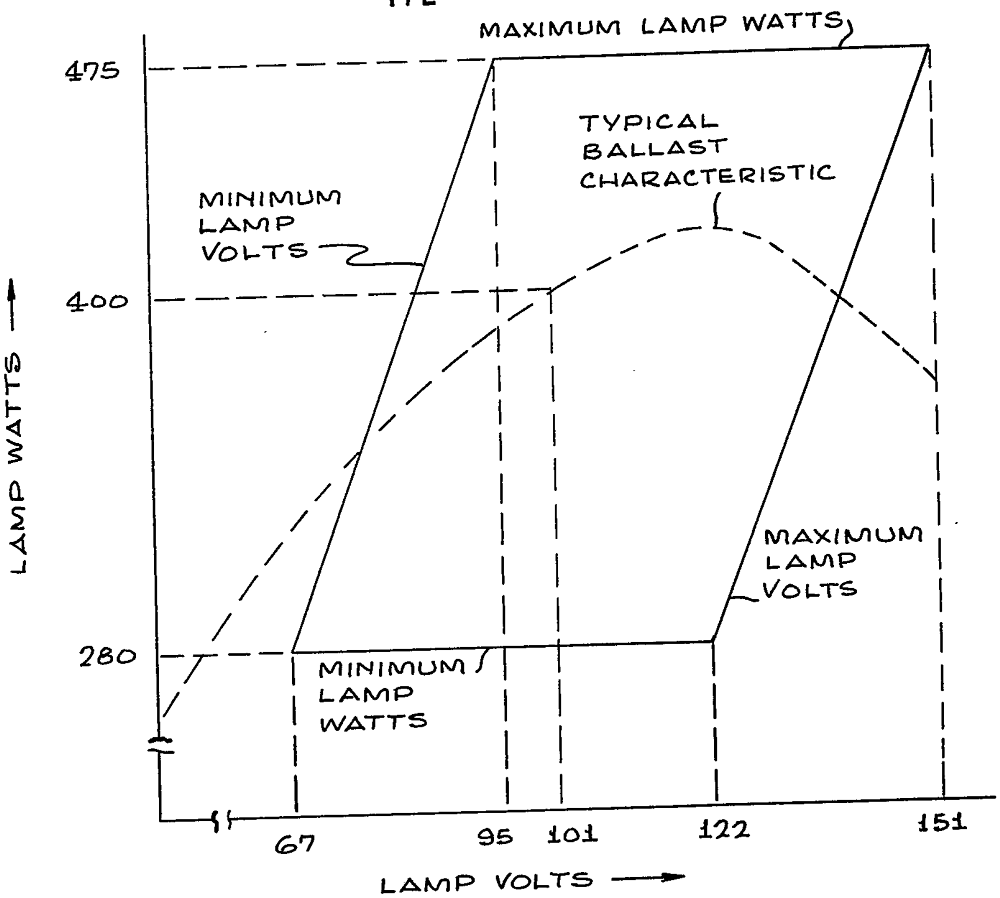
MAXIMUM LAMP WATTS
TYPICAL BALLAST CHARACTERISTIC
MINIMUM LAMP VOLTS
MAXIMUM LAMP VOLTS
MINIMUM LAMP WATTS
475
400
280
LAMP WATTS
67
95
101
122
151
LAMP VOLTS

FIG. 1

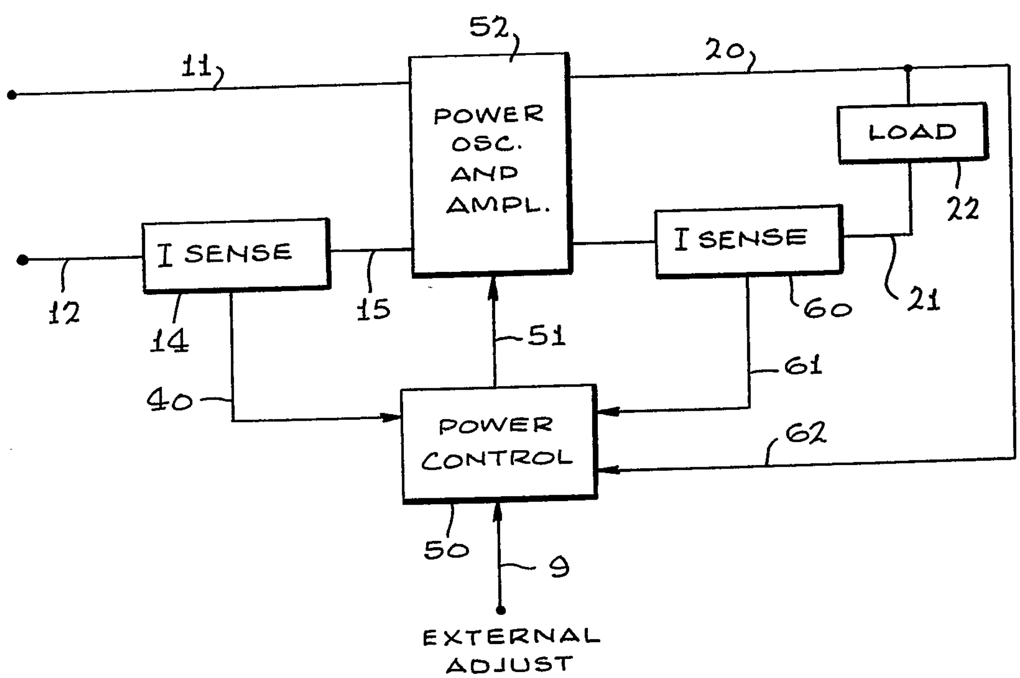
11
52
20
POWER OSC. AND AMPL.
LOAD
22
I SENSE
I SENSE
12
14
15
60
21
51
61
40
POWER CONTROL
62
50
9
EXTERNAL ADJUST

FIG. 2

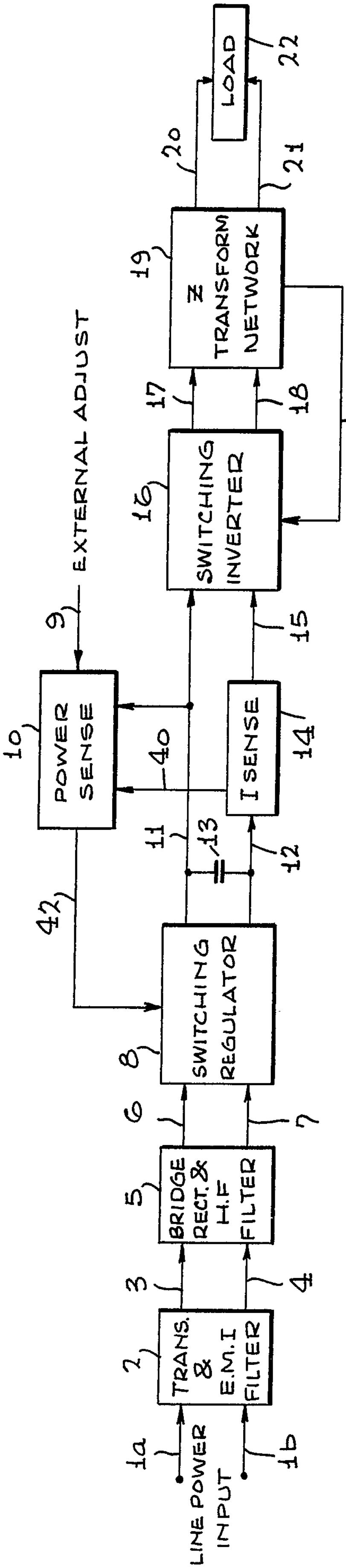
LINE POWER INPUT
1a
1b
TRANS. & E.M.I FILTER
2
3
4
BRIDGE RECT. & H.F FILTER
5
6
7
SWITCHING REGULATOR
8
42
POWER SENSE
10
9
EXTERNAL ADJUST
40
11
13
12
I SENSE
14
15
SWITCHING INVERTER
16
17
18
Z TRANSFORM NETWORK
19
23
20
21
LOAD
22

FIG. 2

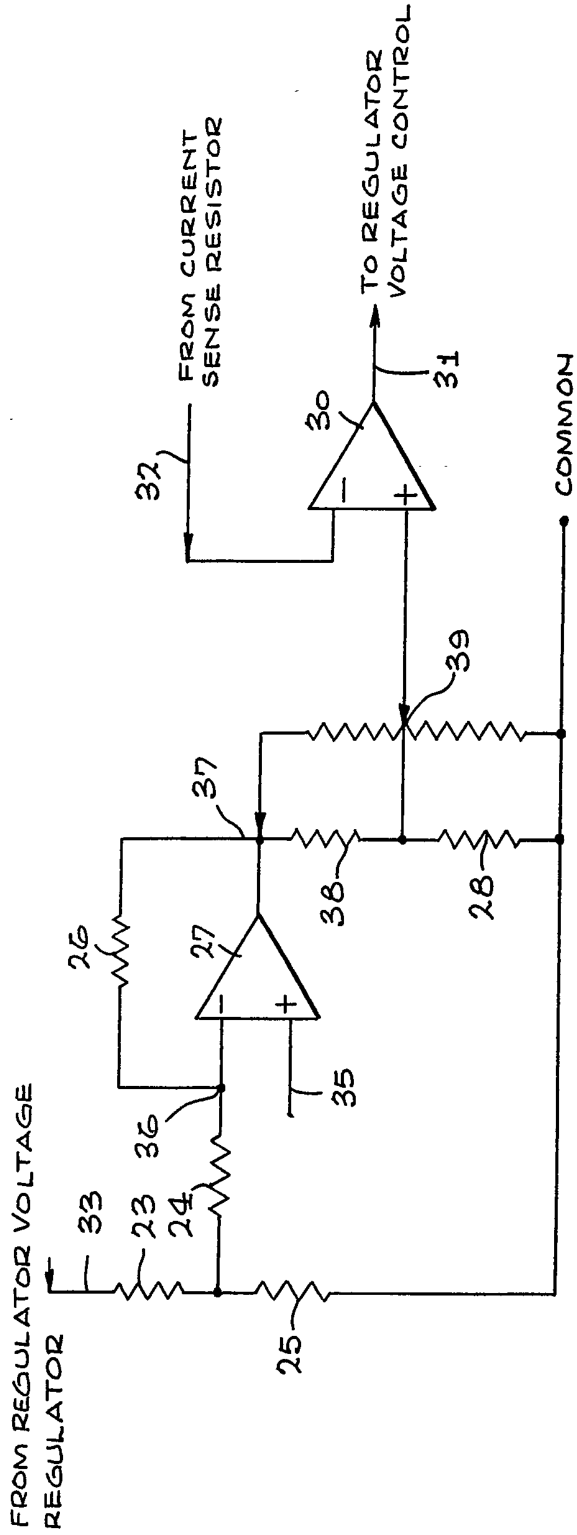
FROM REGULATOR VOLTAGE REGULATOR
33
23
24
25
36
35
26
27
37
38
28
39
COMMON
FROM CURRENT SENSE RESISTOR
32
30
TO REGULATOR VOLTAGE CONTROL
31

FIG. 3

SPECIFICATION

Constant power ballast for gas discharging devices

Gas discharge light sources such as high intensity mercury vapor, high pressure sodium, and low pressure mercury such as fluorescent lights, have a negative impedance characteristic and must be run with a ballasting device that will produce a constant current through the lamp regardless of impedance changes. As the tube ages or its environmental conditions change, the impedance will also change. If the current is truly held constant, the power, therefore, the light output, of the lamp will either decrease or increase subject to the impedance changes. This is an undesirable characteristic. The invention disclosed herein serves to maintain a constant power delivered to the lamp regardless of the impedance characteristic; thus, as the tube ages it light will remain relatively constant. The invention may also supply a slight increase in power over the life of the discharging device to make up for the slight loss of efficiency that occurs as the device ages thus producing constant light output over the life of the lamp.

Up to very recently, the ballasting of gas discharge type light sources has been accomplished with a reactive device that limits the current flow. These devices have been improved gradually over the years to maintain a high power factor by utilizing a transformer or auto transformer configuration with a high leakage reactance between the primary and secondary in conjunction with a capacitor to correct for the lagging power factor. The high leakage reactance has the effect of producing a somewhat constant current in the discharge while limiting the primary input current. Optimum light output with this type of ballast is achieved when the lamp impedance is equal to that for which the ballast was designed while operating at the correct rated line voltage. Variations in the input line voltage which normally occur will cause a corresponding variation in the current and energy delivered to the gas discharge, thus increasing or decreasing the light output.

As the lamp ages, the impedance will increase. In high intensity discharge lamps, this effect is very evident. When the lamp is first placed in service, it has a very low impedance and since the current that can flow from the ballast is limited, a lower than rated light output is normally the result. As the lamp ages, the increasing impedance along with a constant current, causes the light output to increase. In order for the current in the discharge to remain constant as impedance increases, the ballast necessarily must develop a higher output voltage. The amount this voltage can rise is deliberately limited by the ballast transformer design to prevent too much power being delivered to the lamp. This necessary voltage limitation, however, causes the current through the lamp to drop as the lamp further ages, and its impedance rises. At this point in the lamp life, the light output will also start to drop. This phenomena is particularly evident in fluorescent lighting where the lamps are enclosed within a fixture that gets quite hot. This increases the lamp impedance past the constant current point of the ballast and lowers the light output. What few high frequency ballasts that have been developed in the marketplace have given this phenomena very little attention and, therefore, cannot reasonably be considered prior art.

It is the object of this invention to provide constant power to a gas discharge light source regardless of impedance changes over the life of that device.

It is another object of this invention to provide constant power resulting in constant light output to a gas discharge light source regardless of the changes in impedance caused by varying environmental conditions surrounding that light source.

Yet another object of this invention is to provide for a slight increase in light output as a function of light source impedance changes caused by aging when such a light source efficiency diminishes with life, and, in this manner creating a constant light output.

A final object of the invention is to apply any of the aforementioned three objects to any form of gas discharge whether or not the generation of light is the intended purpose.

These and other objectives are achieved in accordance with the present invention by providing a high frequency power supply that delivers an essentially sineusoidal voltage and current wave form to the gas discharge in such a manner that the product of the voltage and the current will remain constant or increase slightly at a predetermined rate as the function of the gas discharge impedance change, the result of aging of the gas discharge device.

The power supply, or ballast, is comprised of five major sections:

1. A DC power supply broken into three subsections:

a. An EMI rejection filter both for incoming and/or outgoing EMI.

b. Line rectification producing pulsating DC current, and

c. A switching regulator to convert this pulsating DC into a steady controlled DC output.

2. A switching inverter to develop the appropriate high frequency broken into two subsections:

a. The switching devices whether full or half bridge, and

b. The switching device drive section.

3. A signal conditioning and tuning network designed to produce through the means of feedback to the drive section of the switching regulator a sineusoidal current load on the output of said current regulator to reduce stress on the switching transistor and a sineusoidal voltage and current wave form to be presented to the gas discharge load.

4. A pulsating device that works in conjunction with one of the network inductors to produce high voltage striking pulses necessary to originally initiate gas discharge.

5. A current and voltage detection means which adjusts the output of the switching regulator section to maintain the wattage dissipation in the gas discharge constant.

Alternately, item 2 above may be a power oscillator and amplifier encompassing the load as an integral portion thereof. In this case, the adjustment discussed in item 5 could be a gain control.

Objects and features of the invention will be apparent from a consideration of description when taken in connection with the accompanying drawings in which like numbers of reference denote corresponding parts throughout the several views, in which:

Figure 1 is a graphic representation of the typical high intensity discharge lamp. This particular graph depicts data associated with a 400 watt high pressure sodium lamp. The trapazoid depicts the boundaries within which the lamp may be operated. The dashed line indicates the performance of this lamp when used with the typical conventional core and coil ballast. The dot-dash line shows operation when the lamp is used with subject invention ballast;

Figure 2 is an electrical block diagram of the inventive power supply for constant power operation of a gas discharge;

Figure 3 is a schematic diagram of one of the methods by which a switching regulator's output may be modified to produce constant power to the switching regulator and thus to the load; and

Figure 4 is another method by which operation as depicted in the block diagram of Figure 1 may be accomplished.

The following detailed description is of the best presently contemplated modes of carrying out the invention. The description is not to be taken in a limiting sense but is made merely for the purpose of illustrating the general principles of the invention since the scope of the invention is best defined by the appended claims. Operational characteristics attributed to forms of the invention first described also shall be attributed to forms later described unless such characteristics obviously are unapplicable or unless specified exception is made.

In referring to Figure 1, it can be seen that there is a very wide range of operational characteristics into which a lamp such as a high pressure sodium may fall. As an example, when a new lamp is put in service, the wattage input, and therefore, the light output could be as low as 280 wattsa. By observing the dashed line, we see that with the conventional ballast the light output would normally be that produced by 320 watts of power. However, this is calculated at nominal line voltage. At low line voltage this wattage output will be still less. It can also be seen that at the end of life of the lamp, the light output could be as high as 475 watts and still be within acceptable lamp characteristics. This is a highly undesirable feature, however, and as can be seen by observing the conventional ballast, the light output has again fallen off caused by limitation imposed by the ballast. Thus, the only time the light actually produces its rated output of 400 watts is at the center of its life cycle with the appropriate input line voltage. This wide a deviation in light output especially at the low end requires that architects provide an adequate number of fixtures to produce the necessary illumination both at the beginning and end of lamp life and at low line conditions. It can be readily observed from this data that a better ballast has been needed for some time.

The dot-dash line depicts the inventive ballast disclosed herein operational characteristics and is essentially a flat, straight line producing constant light output over the entire life of the lamp. This line is drawn at a lower wattage than the 400 rated for the lamp because the high frequency operation requires less input power to produce the same rated light output achieved with a conventional 60 Hz and coil ballast. In preexisting installations where more fixtures have been installed than are required with the inventive ballast due to the higher maintained light level, the inventive ballast provided for an adjustment to lower the power to the lamp all the way down to 280 watts if necessary. In this manner, energy is conserved, and the life of the lamp is increased. The constant light on the illuminated area may also provide efficiency improvements.

The dotted line shows a slight increase in wattage output as the lamp impedance increases. This is to compensate for the slight decrease in efficiency of the lamp as it ages and provides what is known in the trade as "constant lumin maintenance." The effect of utilizing the pure sineusoidal high frequency combined with the lumin maintenance provided by the controlled power to the lamp can produce situations where high pressure sodium has been carefully designed into an application at savings as high as 40 percent in energy/consumption. Such savings, of course, far more than justify an increase in cost if necessary of the inventive ballast over the conventional core, coil, and capacitor construction.

In referring to Figure 2, line input power enters on lines 1a and 1b through filtering network 2. This network provides transient noise attenuation to protect the subsequent circuit components. In addition, the filter is designed to prevent switching transients created within the ballast from being imposed upon the power line in the form of conducted EMI. Thus filtered, the line power is presented via lines 3 and 4 to bridge rectifier and high frequency filter 5. Here, the signal is converted from AC to pulsating DC. The output appears on 6 and 7 as 120 Hz pulsating direct current. Through the means of unique switching regulator concept 8 in conjunction with large filter capacitor 13, the pulsating DC is converted to a filtered direct current whose level may be controlled by means external to switching regulator 8. The unique function of this switching regulator is more completely detailed in copending application Serial Number

The filtered direct current output appearing on capacitor 13 is presented by line 11 and through current sense 14 by line 15 to the switching inverter 16. The switching inverter via lines 17 and 18 presents an alternately polarized square wave voltage to network 19. A feedback signal on line 23 controls the frequency of the switching inverter in order that the network in combination with the load 22 will always be in resonance.

The network 19 performs an impedance transformation. As previously discussed, the load current must be held constant. The transformation is such that the current is a direct function of the input voltage and is not dependent on the load impedance. Thus, with the input voltage to the switching inverter 16 held constant, the current in the lamp will be constant. As the lamp 22 ages, its impedance will rise. The power dissipated within the load is equal to the current squared times the load resistance, and, therefore, as this resistance increases, the power must necessarily rise. With the voltage held constant, the network will demand more current from the inverter to accomplish this result. The current demand is sensed by current sense 14.

The output of the current sense 40 indicating the amount of current flowing is compared to the input voltage on line 11 by the power sense unit 10. The output of the power sense unit then regulates via line 42 the output voltage of the switching regulator. The product of the voltage and the current is equal to the predetermined maximum allowable power to be dissipated in the arc discharge.

Figure 3 depicts a schematic representation of how the above may be accomplished. Operational amplifier 30 is a portion of an integrated circuit designed to operate switching regulators. The negative input is supplied by the voltage drop across a current sense resistor on line 32. By selecting the value of the current sense resistor, the maximum current that will be allowed to flow from the switching regulator is determined. In normal operation, the positive junction of this amplifier is operated at ground potential; thus, when the circuit commences to draw excessive current, the voltage on line 32 rises until the output of operational amplifier 30 causes the voltage of the switching regulator to drop to that point where the current is below the maximum predetermined amount. In the circuit depicted in Figure 3, the regulator output voltage is fed by line 33 to voltage divider 23 and 25, the center point of which is connected via input resistor 24 to the summing injunction 36 of operational amplifier 27. The positive input of the operational amplifier 35 is connected to a referenced voltage.

The output of amplifier 27 at point 37 is applied to a voltage divider comprising resistos 38 and 28 the junction of which is connected via line 39 to the positive input or reference point of operational amplifier 30. Thus, point 39 is raised above ground by a predetermined amount requiring the current sense feedback on 32 to be euqal to this voltage. As the voltage at point 39 is raised or lowered, the maximum amount of current that is allowed to flow will consequently be raised or lowered appropriately.

By observing the whole circuit operation, it can be seen that as the regulator output voltage increases, the maximum amount of current that is allowed to flow is reduced; and, as the regulated output voltage is lowered, more current can flow. The values are adjusted such that the product of the voltage and current will remain a constant. This simple circuit is quite satisfactory for most HID applications where the lamps are run at or near their maximum light output for their entire life. In the event it is desirable to control power at different preset levels, resistors 38 and 28 may be substituted for a potentiometer 34 shown in dotted lines.

Figure 4 depicts a block diagram of a power oscillator amplifier and constant power control system that would replace the switching inverter and network at lines 15 and 12 in Figure 1. In this method of developing the output signal to the lamp load, the voltage from the switching regulator is held constant, and the gain of the amplifier is adjusted to control the power delivered to the load. This is more thoroughly discussed in a co-pending patent application. With the voltage held constant, the power directly proportional to the current flowing through the amplifier. Thus, a power control 50 senses the amount of current flowing and adjusts the gain to maintain that current constant, and, in this manner, assures the energy flowing into load 22 via lines 20 and 21 will not vary regardless of this load impedance. An external adjust 9 may be applied to the power control to adjust the energy and, therefore, the light output emitted from the lamp.

The power control may also be supplied with the indication of lamp current through lamp current sensor 60 and line 61 and lamp voltage through line 62. In this manner, the power sense may compute the impedance of the lamp which as previously discussed increases with age. Thusly, as the lamp ages, the power control can supply slightly more energy to the lamp and compensate for the lamp's decreasing efficiency thus maintaining a constant lumin output.

In the circuits depicted in Figure 2 and detailed in Figure 3, this same result may be achieved by properly selecting the values surrounding operational amplifier 27 and the related voltage dividers. This is possible as the voltage and current ratio entering the switching inverter will change with the aging of the lamp even though the product is calculated to be held constant. By observing the change in this voltage to current ratio, the appropriate wattage may be supplied to the lamp to compensate for this decrease in light generating efficiency.

CLAIMS

1. A constant power ballast for gas discharging devices comprising a switching regulator presenting a unity power factor to a line power input a switching inverter coupled to receive a steady controlled DC output from the switching regulator, a transformer network operably interposed between the switch inverter and the gas discharge device for presenting a high frequency to the gas discharge device and a signal conditioning and tuning network coupled to the switching regulator for producing a sineusoidal current load at the output of the switching regulator.

2. A device as claimed in claim 1, in which a current and voltage detection means is provided for adjusting the output of the switching regulator to maintain the wattage dissipation in the gas discharge device constant.

3. A device as claimed in claim 2, in which the switching inverter is a power oscillator and amplifier encompassing the gas discharge device as an integral portion thereof.

4. A device as claimed in claim 2, in which the conditions and tuning network includes inductors

and a pulsating device operably coupled to a selected one of the inductors to produce high voltage striking pulses necessary to originally initiate gas discharge.

5. A device as claimed in claim 4, in which the conditioning and tuning network constitutes a feedback network.

6. A device as claimed in claim 1, in which the switching inverter includes switching devices of the full or half bridge type, the switching device being the drive section therefor.

7. A device as claimed in claim 5 or 6, in which a DC power supply having an EMI rejection filter both for incoming and outgoing EMI is provided together with a line rectification means for producing pulsating DC current connected to the switching regulator.

8. In a high frequency power supply a combination comprising means for delivering an essentially sineusoidal voltage and current wave form to a gas discharge device in such a manner that the product of the voltage and current will remain constant or increase slightly at a predetermined rate as the function of the gas discharge impedance change and the result of aging of the gas discharge device.

9. A constant power ballast for gas discharging devices constructed and arranged to operate substantially as herein described with reference to and as illustrated in the accompanying drawings.

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